UTAH DIVISION OF WATER QUALITY
195 North 1950 West
PO Box 144870
Salt Lake City, Utah 84114-4870

Willard Bay Project Proposal Form

NOTE: Proposal must be **no longer than 6 pages**. Supplemental documents such as letters of support, information to demonstrate previous project implementation and other relative supportive documents may be submitted in addition to this form.

Applicant Name: Dennis L. Newell

Co-Applicant Name(s): James Evans

Project Title: Hydrogeochemical characterization of the Willard Bay aquifer system: complex interplay of mountain front recharge, Bear River basin recharge, and deep hydrothermal inputs.

Agency or Business Name: Department of Geology, Utah State University

Mailing Address: 4505 Old Main Hill, Logan, Utah 84322

Phone: (435) 797-0497 E-mail: dennis.newell@usu.edu

☐ Individual ☐ Non-Profit ☐ Govt. Agency **X** Academic ☐ Commercial ☐ Other

1. Estimated Project Costs:

Labor	$147,900 (PI, Co-I, students, Post Doc, fringe)
Materials	$54,000 (Sampling materials and analysis)
Equipment	$0
Administration	$23,000 (USU F&A discounted from 38.4% to 10%)
Miscellaneous	$27,300 (Tuition for 2 MS students)
TOTAL	$252,200

Other sources of project funding:

USU Dept. of Geology	$30,000	(Teaching Assistantship Support)

Total project cost including other sources of funding: $282,200

2. Purpose and Need of Project:

Introduction

Few, if any, locations in the western U.S. have such a confluence of anthropogenic, biological, ecological, hydrogeological and geochemical processes as in the narrow corridor between the Wasatch Mountains and Willard Bay (Figure 1). Critical to evaluating the future environmental impact of the Willard Bay diesel spill and its associated remediation and the long-term management of the local ecosystem are determining the temporal and spatial variability of the surface and groundwater quality. While the hydrogeological systems to the north (Brigham City region) and the south (Ogden) have been relatively well characterized (e.g., Bjorklund and McGreevy, 1974; Anderson et al., 1994; Hurlow, 1999), information on the Willard Bay corridor is sparse (e.g., Bjorklund and McGreevy, 1974; Lund, 1980). We propose to construct a comprehensive hydrogeochemical assessment of the interconnected surface and groundwater systems to provide a framework for maximum beneficial use of the Willard Bay hydrological system. This project will also provide a significant educational benefit through training of graduate and undergraduate geology students at Utah State University. Additionally, data from this project will be made available to the many stakeholders in the region, such as residents, private businesses and state and federal agencies.

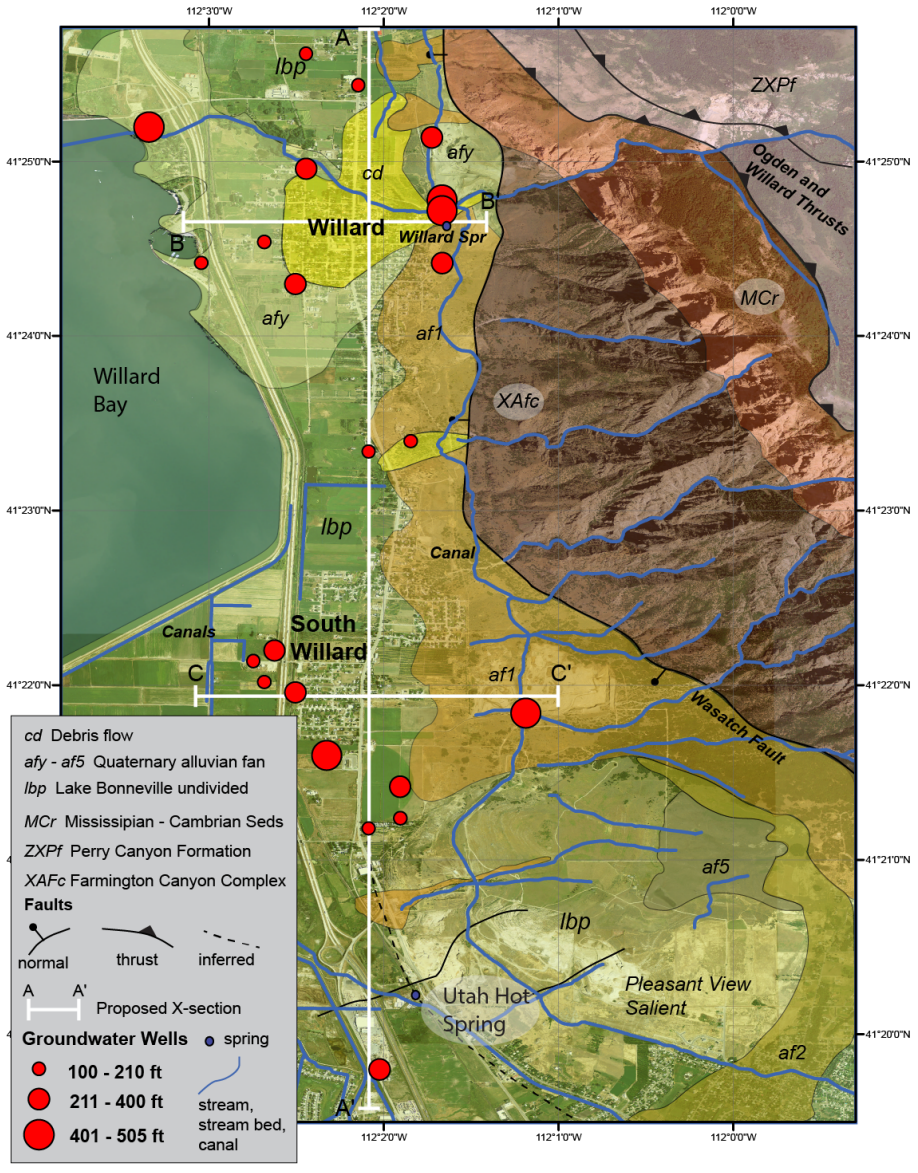

Figure 1. Simplified geologic map of study area (after Personius, 1990). Select existing groundwater wells are shown according to depth. Major stream valleys (seasonal), springs and canals that may contribute to Willard Bay hydrologic system are shown. Three proposed cross-sections are shown for characterizing the hydrogeology and hydrogeochemistry of the Willard aquifer system.

Willard Bay Corridor Hydrogeological System

Numerous geographic and geological factors control the amount and pathways of groundwater recharge, its distribution in the subsurface and its chemistry. The Willard Bay corridor is bounded to the east by the remarkably steep Wasatch Mountain front, which has been uplifted along the Wasatch normal fault (Machette et al., 1991). Relatively rapid exhumation along this fault has resulted in a steep mountain front rising abruptly to elevations of nearly 3000 meters in less than 5 km. The active fault moves 2 – 4 m every 1000 – 1500 yrs. (Bruhn et al., 2005). The Wasatch front is composed of Precambrian metamorphic rocks and Cambrian – Mississippian sedimentary rocks (Fig. 1). These are in fault contact to the west with basin fill sedimentary material associated with ancient Lake Bonneville, the present day lake and Bear River system, and alluvium delivered from the Wasatch mountains. The deepest borehole in the region was drilled to a depth of 1205 ft (367 m) near the South Willard Bay recreation site and encountered inter-bedded sand, silt and clay over its entire length (Lund, 1980). This type of stratigraphy results in a layered aquifer system with more permeable sand-rich units confined above and below by clay-rich horizons. Groundwater wells along the Willard corridor appear to target zones ~100 ft (30m), between 200 and 400 ft (60 – 122 m), and as deep as 505 ft (154 m) (Fig. 1), presumably targeting sand rich horizons. Sediments in the basin also coarsen to the east due to alluvial fan and debri flow delivery from the mountain front.

Groundwater recharge to this layered aquifer system is delivered from sources including snowpack fed mountain front recharge, the Salt Lake basin - Bear River alluvial system, losses from canal systems and irrigation, and from deep thermal fluids. The relative contribution from these sources is quite uncertain. Mountain front (or block) recharge (Fig. 2) is the proportion of groundwater sourced from meteoric water (snow, rain, stream) infiltration through the fractured bedrock east of the Wasatch Fault and may be 30 – 60% of total groundwater volume in basins (e.g., Manning and Solomon, 2005; Gleeson and Manning, 2008). The depth of circulation into the adjoining basin to the west depends on the elevation head of the percolating water. Geochemically, these waters are generally of good quality and carry a signature of relatively high altitude infiltration and rock-water interaction with crystalline bedrock (Manning and Solomon, 2005).

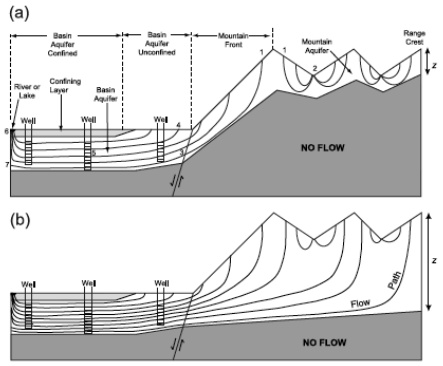

Figure 2. Examples of mountain front (block) recharge along a fault bounded mountain front (Manning and Solomon, 2005).

In contrast, alluvial waters derived from the Bear River, ancient Lake Bonneville, and recharge from irrigation returns or present-day Willard Bay will likely have diverse water chemistries and variable water quality (good to poor). Long-term residential, commercial and industrial use of the Willard corridor likely also has had impacts to surface and groundwater quality. This corridor is also unique because the deeply penetrating Wasatch Fault provides flow paths of deep thermal fluids to the surface as evidenced by the numerous hot springs found along the Wasatch front. These relatively small volume fluids can have a significant impact on water geochemistry and quality (e.g., Newell et al., 2005). For example, Utah Hot Spring (Fig. 1),

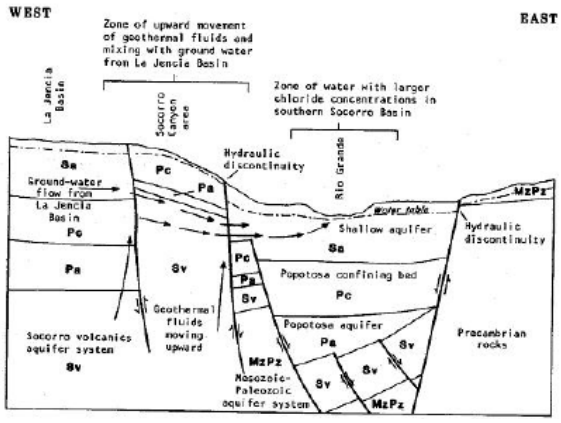

Figure 3. Example of deep geothermal fluid migration along basin bounding faults percolating into shallow aquifers in the Socorro basin, New Mexico (Anderholm, 1984).

has total dissolved solids of ~25,000 ppm and arsenic contents twice the EPA drinking water standard (Murphy and Gwynn, 1979; Newell, unpublished data), and Crystal hot springs north of Brigham City has arsenic contents 7X the drinking water standard (Newell, unpublished data). Deep fluid inputs to the groundwater are likely along the entire length of the fault, regardless if hot spring discharges are observed. Evidence for similar blind recharge along faults to shallow aquifers has been observed in numerous locations of the western U.S. (Figure 3) (e.g., Newton, 2004; Newell et al., 2005; Williams et al., 2013).

Further complicating the potential impacts to surface and groundwater is the extremely diverse industrial land uses along this narrow corridor. These include diesel and natural gas pipelines, two major highways, the railroad, and large gravel operations. Stakeholder who have a vested interest in preserving the surface and water quality of the Willard corridor include the local municipalities and residents, agriculture (livestock, produce, fruit), Utah State (Environmental Quality, Water Quality) and Federal (USFS, USDA, USFWS) land.

3. Estimated time frame of the project with significant milestones

The project will be completed over a four-year period starting summer 2014. General tasks and milestone are as follows:

- Year 1: Identify graduate student (M.S. or Ph.D.); obtain access to wells and surface water for sampling; data mining for geologic well logs, water quality data and other relevant information; begin sampling and analysis
- Year 2: Complete first cycle of sampling and analysis; begin construction of GIS-based maps with water quality data; identify key locations (well, streams, springs) based on chemistry and locations for monthly monitoring over next 2 years
- Year 3: Recruit graduate student (M.S.); monthly sampling and analysis; begin construction of detailed cross-sections (Fig. 1) with geological and geochemical data; identify key parameters (e.g., temperature, stable isotopes) for quantifying recharge components
- Year 4: Monthly sampling and analysis; complete cross-sections; quantify recharge components; finalize GIS-based maps with hydrogeochemical data; produce final project report by January 1, 2018.

4. Describe location of the project with attached location map, including total area that will be directly enhanced by the project.

Figure 1 (Section 2) depicts the proposed study area. The three cross-section lines delineated the approximate extent of the area that the study will encompass (~10 km X 5 km).

5. Describe how the project will specifically enhance and protect waterways affected by the Willard Bay diesel release and improve the conditions of one or more of the following: wildlife, habitat, natural vegetation, water quality or emergency response:

The proposed project will construct a data framework for maximum beneficial use and long-term management of the Willard Bay corridor natural resources. Data collected over the four-year period will quantify the vertical and spatial distribution of water quality in the local aquifers between the Wasatch front and Willard Bay. Additionally, the monthly monitoring over the duration of the project will identify any temporal variability due to seasonal inputs. Understanding the variability in local water quality will provide land managers, stakeholders and property owners with critical information for evaluating proposed land use changes and emergency response strategies for incidents like the diesel spill.

6. Describe project's connectivity to other natural areas or projects that further enhance wildlife, habitat, natural vegetation, water quality or emergency response:

Other nearby projects that are connected to the proposed work include the U.S. Geological Survey Groundwater study of the Malad/Lower Bear River Hydrographic Area, the Utah Geological Survey Lower Bear River and Malad River basin Geologic Framework Study, and the Willard Spur Research Program coordinated by the Utah Division of Water Quality. These studies focus primarily on the Lower Bear river hydrology, associated groundwater systems, and nutrient contributions and cycling in Willard Bay and surrounding wetlands. This study will provide key data on the groundwater quality and contributions along the Willard corridor, including the contributions from the Wasatch Mountain front, which are not objectives of the ongoing studies.

7. Describe any social benefit of implementing this project:

This project will involve both graduate and undergraduate students providing rich educational experiences in understanding the controls on groundwater recharge and quality in a mixed-used area. Additionally, the project will require working with the local municipalities, residents, commercial interests and state and federal agencies for access to surface and groundwater. The goal is not only to work with these stakeholders for access, but also to educate and to provide currently unavailable water quality data.

8. Project plans and details, including rights to work on the specific piece of land:

We propose to estimate the amount, quality and pathways of mountain block recharge and proportion of upwelling thermal ground waters influencing the aquifers along the Willard Bay corridor. This research will form the basis of M.S. or Ph.D. student thesis research at Utah State University. Groundwater will be characterized through testing and sampling of existing water wells along the Willard Bay corridor (Fig. 1.) These wells penetrate depths between 30 and 150 m, providing access to ground waters residing in different aquifer units. In addition to characterizing the groundwater, we will also conduct monthly sampling and analysis throughout the study duration of recharge surface waters fed from the Wasatch front (streams on Fig. 1). These streams have the highest flow rates during spring runoff and drop in discharge through the summer season. Some of the streams do have perennial flows in their upper reaches and have been observed to disappear at the mountain front due to infiltration into the permeable alluvial deposits.

During water sampling, pH, specific conductivity and temperature will be measured. If possible, the depth to groundwater will be sounded in wells. Water samples will be analyzed for stable isotopes of H, C and O at the USU Department of Geology Stable Isotope Lab, and for major and trace element composition at the USU Water Research Lab. To the extent possible, geological information from existing well logs will be used to characterize the stratigraphy of the Willard Bay corridor shallow aquifers. These data will be used to construct maps and cross-sections of water temperature, stable isotope, and elemental composition. Three cross-sections are depicted on Figure 1 that will guide the collection and presentation of data. This project will require access to surface water and wells on federal, state and private land. We do not anticipate significant problems in gaining these permissions. The USU Department of Geology currently has a relationship with the canal authority for access to canyons and the Wasatch Fault, just east of Willard, for geology field trips, classes, and student research.

9. Describe your experience in implementing projects of similar scope and magnitude:

PI Newell has extensive experience organizing and managing multi-year hydrogeological investigations gained at Los Alamos National Laboratory. These projects were focused on delineating the nature and extent of vadose zone and groundwater contamination related to past chemical and radioactive waste

releases. Co-I Evans is an experienced researcher that has managed numerous multidisciplinary projects funded by the Department of Energy, the National Science Foundation, and other state agencies.

10. Describe how ongoing maintenance of the project will be funded and carried out:

This characterization project will not require ongoing maintenance.

11. List consultants or agency partners that have participated in project development:

Not applicable.

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Anderholm, S. K., 1984, Hydrogeology of the Socorro and La Jencia basins, Socorro County, New Mexico, USGS Water Resources Investigations Report 84-4342.

Anderson, P. B., Susong, D. D., Wold, S. R., Heilweil, V. M., and Baskin, R. L., 1994, Hydrogeology of recharge areas and water quality of the principal aquifers along the Wasatch Front and adjacent areas, Utah: U.S. Geological Survey Water-Resources Investigations Report 93-4221.

Bjorklund, L. J., and McGreevy, L. J., 1974, Ground-water resources of the Lower Bear River drainage basin, Box Elder County, Utah: U.S. Geological Survey, U.S. Geological Survey Technical Publication No. 44.

Bruhn, R. L., DuRoss, C. B., Harris, R. A., and Lund, W., 2005, Neotectonics and paleoseimology of the Wasatch fault, Utah, *in* Pederson, J., and Dehler, C. M., eds., Interior Western United States: Geological Society of America Field Guide 6, Geological Society of America, p. 231-250.

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Lund, W., 1980, Geology for planning purposes, Willard Bay State Recreation Area, UGMS n0. 151.

Machette, M. N., Personius, S. F., Nelson, A. R., Schwartz, D. P., and Lund, W., 1991, The Wasatch fault zone, Utah - segmentation and history of Holocene earthquakes: Journal of Structural Geology, v. 13, p. 137-149.

Manning, A. H., and Solomon, K., 2005, An integrated environmental tracer approach to characterizing groundwater circulation in a mountain block: Water Resources Research, v. 41, p. 1-18.

Murphy, P., and Gwynn, J. W., 1979, Geothermal investigations at selected thermal systems of the northern Wasatch Front, Weber and Box Elder counties, Utah, DOE/ET/28393-18.

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Newton, T., 2004, Geologic controls on shallow groundwater quality in the Socorro basin, New Mexico [M.S.: New Mexico Institute of Mining and Technology, 174 p.

Personius, S. F., 1990, Surficial geologic map of the Brigham City segment and adjacent parts of the Weber adn Collinston segments, Wasatch Fault zone, Box Elder and Weber counties, Utah: U.S. Geological Survey Misc. Investigations Series Map I-1979.

Williams, A., Crossey, L. J., Karlstrom, K. E., Newell, D. L., Person, M., and Woolsey, E., 2013, Hydrogeochemistry of the Middle Rio Grande aquifer system - fluid mixing and salinization of the Rio Grande due to fault inputs: Chemical Geology.

UtahStateUniversity
OFFICE OF RESEARCH AND GRADUATE STUDIES

May 5, 2014
Refer to: #140817

Michael Allred
Division of Water Quality
PO Box 144870
Salt Lake City, UT 84114
mdallred@utah.gov

Subject: Hydrogeochemical characterization of the Willard Bay aquifer: complex interplay of Mountain front recharge, Bear River basin recharge, and deep hydrothermal inputs.

Mr. Allred:

Utah State University (USU) is pleased to submit the above referenced proposal for your consideration and review.

This proposal has been reviewed by Sponsored Programs administration to verify that it meets all necessary criteria and addresses all required compliance issues. Furthermore, if the proposal is awarded, USU agrees to perform the statement of work as outlined in the proposal within the budgetary limits imposed. We are requesting $252,200.00 to support the proposed statement of work.

I certify that I am the Authorizing Official for USU and this office is responsible for contractual matters. The USU principal investigator for the proposed project will be Dennis Newell.

Established in 1888, USU (Utah's sole land-grant institution) is a state-owned, non-profit, institution of higher education. As such, USU requests that any resulting award from this proposal incorporate terms and conditions applicable to its required adherence to Federal OMB Circulars A-21, A-110, and A-133, as well as its need to comply with the laws of the State of Utah.

Please send all contractual and/or administrative correspondence, including all award and/or modification documents requiring signature, to my attention at: sponsoredprograms@usu.edu or Utah State University, Sponsored Programs, 1415 Old Main Hill – Room 64, Logan, UT 84322-1415.

Please feel free to direct questions of a technical nature or regarding the statement of work to Dennis Newell at dennis.newell@usu.edu . Questions of a contractual or administrative nature should be directed to the undersigned at Kellie.Hedin@usu.edu.

Sincerely,

Kellie Hedin

Kellie Hedin
Contract Administrator

Key Personnel

Hydrogeochemical characterization of the Willard Bay aquifer system: complex interplay of mountain front recharge, Bear River basin recharge, and deep hydrothermal inputs

Biographical sketches for the key personnel for this proposal are attached. Dennis Newell is the Principal Investigator, Jim Evans is the Co-investigator, and Kelly Bradbury is proposed to provide technical support in the role of postdoctoral researcher.

Biographical Sketches - Utah State University: Dennis L. Newell

Education

Ph.D., Earth and Planetary Sciences; University of New Mexico:	2007
M.S., Geology; Colorado State University:	1997
B.S., Geology; New Mexico Institute of Mining and Technology:	1992

Research and Professional Experience

2013 - current	Assistant Professor of Geology, Utah State University, Logan, UT
2009-2012	Geochemist (Scientist 2), Los Alamos National Laboratory, Los Alamos, NM
2007-2008	Postdoctoral Research Associate
2008-2009	Visiting Professor (Geology), Western State College of Colorado, Gunnison, CO
2007-2008	Postdoctoral Associate, Los Alamos National Laboratory, Los Alamos, NM
2000-2004	Principal Geologist, Apogen Technologies, Inc., Los Alamos, NM
1998-2000	Technical Staff Member, Los Alamos National Laboratory, Los Alamos, NM

Publications – Past Three Years

Herring, A. L., Andersson, L., **Newell, D. L.,** Carey, J. W., and Wildenschild, D., 2014, Pore-scale observations of supercritical CO2 drainage in Bentheimer sandstone by sychrotron x-ray imaging: International Journal of Greenhouse Gas Control, v. 25, p. 93-101.

Newell, D. L., and Carey, J. W., 2013, Experimental Evaluation of Wellbore Integrity Along the Cement-rock Boundary: Environmental Science & Technology, v. 47, no. 1, p. 276-282.

Trautz, R. C., Pugh, J. D., Varadharajan, C., Zheng, L., Bianchi, M., Nico, P. S., Spycher, N. F., **Newell, D. L.,** Esposito, R. A., Wu, Y., Dafflon, B., Hubbard, S. S., and Birkholzer, J. T., 2013, Effect of Dissolved CO_2 on a Shallow Groundwater System: A Controlled Release Field Experiment: Environmental Science & Technology, v. 47, no. 1, p. 298-305.

Keating, E. H., **Newell, D. L**., Viswanathan, H., Carey, J. W., Zyvoloski, G., and Pawar, R., 2013, CO_2/Brine Transport into Shallow Aquifers along Fault Zones: Environmental Science & Technology, v. 47, no. 1, p. 290-297.

Williams, A.J., Crossey, L.J., Karlstrom, K.E., **Newell, D.L.**, Person, M., and Woolsey, E., 2013, Hydrogeochemistry of the Middle Rio Grande aquifer system - fluid mixing and salinization of the Rio Grande due to fault inputs: Chemical Geology, v. 351, p. 281-298

Additional Relevant Publications

Newell, D. L., Jessup, M. J., Cottle, J. M., Hilton, D., Sharp, Z., and Fischer, T., 2008, Aqueous and isotope geochemistry of mineral springs along the southern margin of the Tibetan plateau: Implications for fluid sources and regional degassing of CO_2: Geochemisty, Geophysics, and Geosystems, v. 9, p. Q08014, doi:08010.01029/02008GC002021.

Newell, D. L., Kaszuba, J. P., Viswanathan, H. S., Pawar, R. J., and Carpenter, T., 2008, Significance of carbonate buffers in natural waters reacting with supercritical CO_2 - implications for Monitoring, Measuring and Verification (MMV) of geological carbon sequestration: Geophysical Research Letters, v. 35, p. L23403, doi: 23410.21029/22008GL035615.

Jessup, M. J., **Newell, D. L**., Cottle, J. M., Berger, A. L., and Spotila, J. A., 2008, Orogen-parallel extension and exhumation enhanced by denudation in the trans-Himalayan Arun River gorge, Ama Drime Massif, Tibet-Nepal: Geology, v. 36, no. 7, p. 587-590.

Cottle, J. M., Jessup, M. J., **Newell, D. L.,** Searle, M. P., Law, R. D., and Horstwood, M. S. A., 2007, Structural insights into the early stages of exhumation along an orogen-scale detachment: The

South Tibetan Detachment System, Dzakaa Chu section: Journal of Structural Geology, v. 29, p. 1781-1797.

Crossey, L. J., Fischer, T. P., Patchett, P. J., Karlstrom, K. E., Hilton, D. R., Huntoon, P., **Newell, D.,** and Reynolds, A., 2006, Dissected hydrologic system at the Grand Canyon: Interaction between deeply derived fluids and plateau aquifer waters in modern springs and travertine: Geology, v. 34, no. 1, p. 25-28.

Newell, D. L., Crossey, L. J., Karlstrom, K. E., Fischer, T. P., and Hilton, D. R., 2005, Continental-scale links between the mantle and groundwater systems of the Western United States: Evidence from travertine springs and regional He isotope data: GSA Today, v. 15, no. 12, p. 4-10.

Levitt, D. G., **Newell, D. L.**, Stone, W. J., and Wykoff, D. S., 2005, Surface Water–Groundwater Connection at the Los Alamos Canyon Weir Site: Part 1. Monitoring Site Installation and Tracer Tests: Vadose Zone Journal, v. 4, p. 708-717.

Relevant Synergistic Activities

Professional service as a reviewer: Environmental Science & Technology, EOS, G-Cubed, Geochimica et Cosmochimica Acta, Global and Planetary Change, Chemical Geology, Journal of Hydrology, Journal of Sedimentary Research, Geophysical Prospecting, National Science Foundation EAR
Active member: Geological Society of America, American Geophysical Union, Geochemical Society

Collaborators, past 48 months

Birkholzer, JT, LBNL	Shaw, C; University of Montana
Carey, JW, LANL	Stewart, B; University of Pittsburgh
Carrol, S, LLNL	Spycher, NF; LBNL
Capo, R; University of Pittsburgh	Trautz, R; Electric Power Research Institute
Keating, E; LANL	Varadharajan, C; LBNL
Jessup, MJ: University of Tennessee, Knoxville	Viswanathan, H; LANL
Pawar, R; LANL	Zyvoloski, G; LANL
Pugh, JD; Southern Company	

Graduate and Postdoctoral Advisors

M.S. advisor: Dr. Sally Sutton, Dept. of Geosciences, Colorado State University, Fort Collins, CO
PhD advisors: Dr. Zachary Sharp and Dr. Laura Crossey, Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM.
Postdoctoral mentor: Dr. John Kaszuba, Dept. of Geology and Geophysics, University of Wyoming, Laramie, WY.

Graduate Advisees

Trevor Atkinson (current, M.S. student)

Biographical Sketches - Utah State: James P. Evans

Education

Ph.D., Geology, 1987	Texas A&M University, College Station, TX 77843
M.S., Geology, 1983	Texas A&M University, College Station, TX 77843
B. S., Geology, 1981	The University of Michigan, Ann Arbor, MI 48109
B. S., Engineering, 1981	The University of Michigan, Ann Arbor, MI 48109

Research and Professional Experience

July 1997-present	Professor	Department of Geology Utah State University, Logan, UT 84322-4505
July 1991- June 1997	Associate Professor	Department of Geology Utah State University, Logan, UT 84322-4505
January 1987 - June, 1991	Assistant Professor	Department of Geology Utah State University, Logan, UT 84322-4505
December 1997 -2002	Chief Editor	Journal of Structural Geology

Publications – Past Three Years

Kampman, N., A. Maskell, H.J. Chapman, M.J. Bickle, J.P. Evans, G. Purser, Z. Zhou, J. Gattacceca, M. Schaller, P. Bertier, F. Chen, A.S. Turchyn, N. Assayag, C. Rochelle, A. Busch, Drilling and sampling a natural CO_2 reservoir: Implications for fluid flow and CO2-fluid-rock reactions during CO_2 migration through the overburden, in press, Chemical Geology.

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Pasala, S., Forster, C. B., **Evans, J. P**., and Deo, M., 2013, Simulation of the impacts of faults and fracture systems on CO_2 flow in sandstone reservoirs, *Geofluids*, Early View online. http://onlinelibrary.wiley.com/doi/10.1111/gfl.12029/fullDOI: 10.1111/gfl.12029.

Petrie, E.S., Jeppson, T. N., **Evans, J. P**., 2012, Predicting rock strength variability at stratigraphic interfaces in caprock lithologies at depth: correlation between outcrop and subsurface. *Environmental Geosciences*, v. 19, p. 125-142.

Zhang, Y., Person, M., Rupp, J., Elliot, K., Celia, M., Gable, C. W., Bowen, B., **Evans, J. P**., Bandilla, K., Mozley, P., Dewers, T., and Elliot, T., 2013, Hydrogeologic Controls on Induced Seismicity in Crystalline Basement Rocks Due to Fluid Injection into Basal Reservoirs, *Groundwater*, Early View online, http://onlinelibrary.wiley.com/doi/10.1111/gwat.12071/full, DOI: 10.1111/gwat.12071.

Publications – Relevant to Proposal

Petrie, E.S., Petrie, R.A., Evans, J.P., Identification of reactivation features and increased permeability associated with a fault damage zone using a multidisciplinary approach, J. Structural Geol., v. 59, p.37-49.

Petrie, E.S., Evans, J.P., and Bauer S.J. Failure of caprock seals as determined from mechanical stratigraphy, stress history and tensile failure analysis of exhumed analogs. *Accepted, Am. Association of Petroleum Geologists Bulletin.*

Sonntag, R., Evans, J. P., La Pointe, P., *DeRaps*, M., Sisley, H., *Richey*, D., Sedimentologic controls on the fracture distribution and network development in Mesaverde Group sandstone lithofacies, Uinta Basin, Utah, in: Spence, G. H., Redfern, J., Aguilera, R., Bevan, T. G., Cosgrove, J. W., Couples, G. D. & Daniel, J.-M. (eds)., Advances in the Study of Naturally Fractured Reserovirs, *Geological Society, London, Special Publications* v.374, first published September 10, 2012; doi 10.1144/SP374.4.

Isaacs A. J., **J. P. Evans**, P. T. Kolesar, T. Nohara, 2008, Composition, microstructures, and petrophysics of the Mozumi fault, Japan: In situ analyses of fault zone properties and structure in sedimentary rocks from shallow crustal levels, *J. Geophys. Res*., 113, B12408, doi:10.1029/2007JB005314.

Caine, J. S., **Evans, J. P.,** and Forster, C. B., 1996, Fault zone architecture and permeability structure, *Geology*, v. 18, p. 1025-1028.

Five Relevant Synergistic Activities

- Editor: *Lithosphere*, Geol. Soc. Am., 2008-2011; *Journal of Structural Geology*, 1992-2002.
- NSF-Earthscope National Lecturer, 2011-2012.
- Utah State University: Teaching Professor of the year, College of Science, Utah State University, 1993; Researcher of the Year, College of Science, Utah State University, 1997; USU Honors Program Last Lecturer, 2009; University Graduate Mentor of the Year, 2010.
- American Association of Petroleum Geologists, Energy Professor of the Year, 2013.
- Co-convener, 2013 NSF-sponsored workshop: Drilling of faults and volcanic systems, Park City UT, May, 2013.
- **Collaborators and Co-Editors, past 48 months.**

Chris Ballentine, British Geological Survey	John Garver, Union College
Karl Bandilla, Princeton University	Niko Kampman, Cambridge University
Mike Bickle, Cambridge University	David Kirschner, ExxonMobil
David Blackwell, SMU	Susanne Janecke, Utah State University
Brenda Bowen, University of Utah	Paul LaPointe, Golder Associates
Andreas Busch, Shell Oil	Jeffry Lee, Central Washington University
Michael Celia, Princeton University	Lee Liberty, Boise State University
Duane Champion, USGS Menlo Park	Lisa Morgan, USGS
Judith Chester, Texas A&M University	Peter Mozley, New Mexico Tech
Frederick Chester, Texas A&M University	Dennis Nielson, DES Drilling
Eric Christensen, BYU	Sangeetha Pasala, University of Utah
Milind Deo, Dept. of Chemical Engineering, University of Utah	Mark Person, New Tech
	Alexander Prokopenko, U. South Carolina
Thomas Dewers, Sandia National Labs	John Rupp, Indiana Geological Survey
Kevin Ellett, Indiana Geological Survey	Morgan Schaller, Brown University
Thomas Elliot, Sandia National Lab	Doug Schmitt, University of Alberta
Carl W. Gable, Los Alamos National Lab	John Shervais, Utah State University

- **Graduate and postdoctoral Advisees, past 5 years.**

Dustin Keele (2008) MS.	Chevron, Inc.
David Forand (2010) MS	Chevron, Inc
Kelly Bradbury (2012) PhD	Paris Hills Agricom
Ryan Sonntag (2011) MS	Chesapeake Energy
Corey Barton (2011) MS	Anadarko Petroleum
Elizabeth Petrie (2013) PhD	Utah State University
Rebekah Wood (2013) MS	Utah Geological Survey
Mitchell Prante (2013) PhD	Shell Oil
James Kessler (2014) PhD	current
Santiago Flores (2013) MS	Chesapeake Petroleum
David Richey (2013) MS	Anadarko Petroleum

Kelly Keighley Bradbury, Ph.D, P.G.

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EDUCATION

Ph.D. Geology, Utah State University, Logan UT (2012)
Dissertation Title*: Geological, Geochemical, & Geophysical properties of Fault Rocks at SAFOD: Implications for Fault-related Processes, San Andreas Fault, California.*
Advisor: Dr. James P. Evans

M.S. Geology, Utah State University, Logan, UT (1999)
Thesis Title*: Structural & Hydrogeological Analyses of Deformed Sedimentary Bedrock Aquifers in the Pinebrook Subdivision, Western Summit County, UT*
Advisor: Dr. James P. Evans

B.S. Major: Geology, Minor: Mathematics, Western Michigan University, Kalamazoo, MI (1993)
Undergraduate Thesis Title*: Mapping Buried Bedrock Aquifers Using Geophysical Techniques, Lake Michigan Shoreline, Benton Harbor, MI*
Advisor: Dr. Estella Atekwana

PROFESSIONAL WORK EXPERIENCE

Research Staff & Instructor, Dept. of Geology, Utah State University, Logan, UT (Dec 2013 – present)
Geologist (Contract Position) with DES/DOSECC, Salt Lake City, UT (Dec – Jan 2013)
Senior Geologist (Contract Position) with High Desert Gold Corporation, Denver, CO (March 2013-Jan 2013)
Senior Geologist/Exploration Manager, Paris Hills Agricom, Bloomington, ID (March 2011-March 2013)
Lecturer, Dept. of Geology, Utah State University, Logan, UT (Aug 2012 – Dec 2012)
Research Assistant, Dept. of Geology, Utah State University, Logan, UT (Jan 2008 – March 2011)
Teaching Assistant, Dept. of Geology, Utah State University, Logan, UT (Aug 2007 – Dec 2007)
Field Camp Teaching Assistant, Field Camp, Dept. of Geology, Utah State University, Logan, UT (June 2008)
X-Ray Lab Manager/Technician, Dept. of Geology, Utah State University, Logan, UT (June 2007 – May 2011)
Geologic Consultant, Smithfield, UT (July 2001 – Jan 2007)
Principal Geoscientist, UF^3, North, Logan, UT (June 2002 – Aug 2007)
Environmental Scientist, Cirrus Ecological Solutions, Logan, UT (Aug 1999- Dec 2000)
Consulting Hydrogeologist, BIO/WEST Inc., Logan, UT (Jan - Mar 2000)
Geology Technician, Energy & Geoscience Institute, Salt Lake City, UT (Aug 1997-Dec 1998)
Field Technician, Watershed Science Dept., Utah State University, Logan, UT (Aug 1996)
Research Assistant, Dept. of Geology, Utah State University, Logan, UT (Aug 1994 – May 1997)
Teaching Assistant, Dept. of Geology, Utah State University, Logan, UT (Aug 1994 – May 1996)
Geophysics Field Technician, Dept. of Geology, Western Michigan University, Kalamazoo, MI (Jun 1992 – Oct 1993)

ACADEMIC AWARDS & HONORS

-USU Robins Awards Finalist, PhD Student Researcher of the Year (2010)
-USU College of Science PhD Student Researcher of the Year (2010)
-NSF-ISES (Integrated Solid Earth Sciences) *Rates, Dates, & States*, Selected Participant (2008)
-Peter R. McKillop Memorial Scholarship Recipient, Department of Geology (2008, 2009)
-Utah State University Dept. of Geology Graduate Student Researcher of the Year (1997)
-Western Michigan University Top Senior in Geology Award (1992)

PUBLICATIONS

Bradbury, K.K., Davis, C., Janecke, S.U., Shervais, J., & Evans, J.P., 2014 (*submitted to PAGEOPH special issue)* Micro-scale composition & texture of fault related rocks from SAFOD core and natural analogs: evidence for deformation processes and fluid-rock interactions.

Dinwiddie, C.L., **Bradbury, K.K.**, McGinnis, R.N., Stillman, D.E., & Ferrill, D.A., 2012, Hydrogeologic heterogeneity of faulted & fractured Glass Mountain bedded tuffaceous sediments & ash-fall deposits: The Crucifix site near Bishop, California: Lithosphere, v. 4, p. 44-62.

Bradbury, K.K., Chester, J., Chester, F., Kirschner, Evans, J.P., 2011, Lithology & internal structure of the San Andreas fault based on characterization of Phase 3 whole-rock core in the San Andreas Fault Observatory at Depth (SAFOD) borehole, Earth & Planetary Science Letters.

Jeppson, T. J., **Bradbury, K.K.**, & Evans, J. P., 2010, Geophysical Properties within the San Andreas Fault Zone at the San Andreas Fault Observatory at Depth (SAFOD), & their relationships to rock properties & fault zone structure, Journal of Geophysical Research, 115, B12423, doi:10.1029/2010JB007563.

Bradbury, K.K., Barton, D.C., Solum, J.G., Draper, S.D., & Evans, J.P, 2007, Mineralogical & textural analyses of drill cuttings from the San Andreas Fault Observatory at Depth (SAFOD) boreholes: Initial interpretations of fault zone composition & constraints on geologic models, *Geosphere*, v. 3; doi:10.1130/GES00076.1.

Evans, J.P., & **Bradbury, K.K.,** 2007, Fractured Dirt: deformation textures & processes in sediment & other unconsolidated deposits, Geology, v. 35, p. 671-672.

Dinwiddie, C.L, **Bradbury, K.K**., McGinnis, R.N., Fedors, R.W., & Ferrill, D.A., *2006*, Fault zone deformation overprints & permeability of nonwelded ignimbrite: Chalk Cove fault, Bishop Tuff, California, *Vadose Zone Journal*, 5, 610-627.

Evans, J.P., & **Bradbury, K.K.,** *2004*, Faults & fractures in poorly & non-welded portions of the Bishop Tuff, eastern California: Analogs for unsaturated zone flow at Yucca Mountain, Nevada: *Vadose Zone Journal*, 3, 602-623.

Bradbury, K.K., Evans, J.P., Yonkee, W.A., Lachmar, T.E., *2002*, Structural characterization of folded & fractured sedimentary bedrock aquifers near Park City, Utah: *National Ground Water Association Fractured-Rock Aquifers 2002* - Managing l& use & ground water in the mountainous & upl& areas a conference for elected officials, l&-use planners, & ground water scientists.

Lachmar, T.E., **Keighley Bradbury, K**., & Evans, J.P, 2002, Structure & hydrogeology of deformed sedimentary bedrock aquifers, western Summit County, Utah: Environmental & Engineering Geoscience, v. VIII, no. 3, p. 219-236.

Nielson, D.L., Barton, C.A., & **Keighley, K.E.**, 1998, Comparative study of fractures in core & borehole televiewer in well VC-2B, Valles Caldera, New Mexico: Proceedings, Twenty-third Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 26-28.

Keighley, K.E., & Evans, J.P., 1997, Structural geology applied to the evaluation of fractured sedimentary bedrock aquifers: Pinebrook subdivision, Summit County, Utah: Four Corners Geological Society Symposium *on* Natural Fracture Systems in the Southern Rockies, June 13-14, 1997.

PROFESSIONAL MEETINGS, FIELD TRIPS, & REPORTS

Jonathan Caine, Samuel Haines, and **K. K., Bradbury**, Co-Chair, GSA 2013 National Meeting, Session on Structure and Evolution of Brittle Faults and Fault Rocks: Physical Properties, Geometry, and Geochemical Changes that Influence Water, Energy, and Mineral Resources.

Keighley, K.E., Yonkee, W.A., Ashl&, F.X., & Evans, J.P., 1997, Bedrock geology of the Snyderville Basin: Structural geology techniques applied to underst&ing the hydrogeology of a rapidly developing region, Summit County, Utah *in* Link P.L. & Kowallis, B.J., eds*.,* Mesozoic to Recent Geology of Utah: Brigham Young Univ. Geology Studies, v. 42, p. 325-343.

Keighley, K.E., & Evans, J.P, 1996, Preliminary structural & hydrogeological analysis of the Thaynes Formation; Pinebrook subdivision, Park City, Utah, *in* AEG/UGA Field Trip & Symposium on Ground Water & Fractured Rock in the Snyderville Basin, July 13, 1996.